

CHAPTER 1

AIR AND COMFORT

Section I. INTRODUCTION

1-1. Purpose and Scope

a. The purpose of this manual is to provide a guide and a reference text on sheet metal construction, heating, ventilating, and air conditioning, for use by engineer troops while in training and when in the field.

b. This manual describes the materials and explains the use of tools and equipment used in construction of heating, ventilating, and air conditioning systems. It provides information on the selection, layout, operation, construction, and maintenance of these systems. It covers the principles of sheet metal construction to be used in hot and cold air systems.

c. For additional information relating to the subject matter contained in this manual, consult the *Guide and Data Books* and *Handbook of Fundamentals*, published by the American

Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, New York 10017.

1-2. Comments

Users of this manual are encouraged to submit recommended changes or comments to improve text. Comments should refer to the specific page, paragraph, and line of text pertinent to the recommended change. Correspondence should be forwarded to the Commandant, U.S. Army Engineer School, Fort Belvoir, Virginia 22060.

1-3. Maintenance

Maintenance information for any particular model of equipment mentioned in this manual may be obtained in the appropriate five part manual for that model.

Section II. PROPERTIES OF AIR

1-4. Physical Composition

As it affects human comfort, atmospheric air may be regarded as a mixture of dry air, water vapor, and small quantities of substances generally considered as contaminants such as smoke, dust, bacteria, and odors.

a. *Dry Air.* Dry air is a mixture of gases which averages by volume approximately 78 percent nitrogen, 21 percent oxygen, .03 percent carbon dioxide and .01 percent hydrogen, plus a group made up of argon and other rare gases which total less than 1 percent. The proportions of gases making up this mixture have been found to be substantially constant at all points on the earth's surface. Therefore, they are not considered separately but are treated

collectively as a mixture of gases and called dry air.

b. *Water Vapor.* The amount of water vapor in air varies from almost none at all to the maximum amount that the air can hold, depending upon the weather or upon manmade air conditions. This water vapor may be considered as very-low-pressure steam. It can be condensed and reevaporated in the same manner as ordinary steam.

c. *Contaminants.* Air contaminants are by-products of normal processes, both natural, such as storms or volcanoes, and manmade, such as manufacturing and agricultural processes. These contaminants may be organic (plant or animal matter) or inorganic, visible

or invisible, solid or gaseous, and toxic or harmless. Solid air contaminants may be termed dusts, fumes, or smoke. Dusts include only particles of the larger sizes and may be of mineral, animal, or vegetable origin. Fumes, which are smaller particles, consist of finely divided matter formed by the condensation of vapors from normally solid material such as molten metal. Smokes consist of extremely small solid particles produced by incomplete combustion. Liquid contaminants in the form of airborne droplets are termed mist or fog. Contaminants which are neither solid nor liquid are termed gases if they are normally in the gaseous state, or vapors if they are the gaseous form of substances that are either solid or liquid in their usual state. For example, gasoline is generally in liquid form. The sizes, characteristics, and general methods for removal of airborne particles are listed in tabular form in appendix B.

1-5. Temperature

a. Dry Bulb. The dry-bulb temperature of air is the commonly understood air temperature as registered by an ordinary thermometer.

b. Wet Bulb. The wet-bulb temperature of air is that temperature registered by a thermometer whose bulb is covered by a wick which is wetted and then exposed to a current of rapidly moving air. Evaporation of water from the wick lowers the temperature below that registered by a dry-bulb thermometer. As the rate of evaporation is determined by the amount of water present in the air surrounding the wick, the wet-bulb temperature can be used along with the corresponding dry-bulb temperature to measure or indicate the amount of moisture present in a specific air sample.

1-6. Humidity

a. Definition. Humidity is the water vapor or moisture mixed with dry air in the atmosphere. The amount of moisture can hold varies with the temperature, increasing as the temperature increases. The amount of moisture usually contained in a given sample of dry air is less than the maximum amount possible. The amount of moisture or humidity in the air can be defined as a percentage of the maximum

amount. This percentage is called relative humidity. Air which contains only one-half as much moisture as it could contain at a given temperature is said to have a relative humidity of 50 percent.

b. Humidity-Temperature Relationship. Humidity-temperature relationships are shown graphically on a psychrometric chart in appendix C. This chart plots vertical lines of constant dry-bulb temperature against horizontal lines of constant specific humidity, or weight of water vapor per pound of dry air. Specific humidity is usually expressed in grains per pound of dry air, a grain being 1/7000 pound. The saturation or 100 percent relative humidity line curving upward from the lower left-hand corner of the chart indicates the maximum amount of moisture that air can hold at any given dry-bulb temperature. Between the saturation line and the base line are curving lines of constant relative humidity. Lines of constant wet-bulb temperature slope upward to the left. The complete chart plots the whole range of air moisture and temperature conditions within its limits. Any point on this chart represents a specific condition of air temperature and moisture content and from the point can be read the dry bulb, wet bulb, relative humidity, and specific humidity corresponding to that condition. One other quality, the dewpoint, can also be determined. Dewpoint is defined as the temperature to which an air sample must be cooled in order to produce condensation or "dew". To read the dewpoint, proceed horizontally to the left from a given air condition along a line of constant specific humidity until the saturation line is reached. The wetbulb temperature at the point of saturation is the dewpoint.

c. Humidity Measurement. The amount of humidity can be determined by a hygrometer or a psychrometer. Hygrometers are direct reading instruments indicating relative humidity. Their action depends upon the change in dimension of a hygroscopic substance such as human hair or thin strips of wood which gain or lose moisture and change their dimensions as the humidity changes. These instruments are not accurate unless calibrated frequently

by the more dependable sling psychrometer. A sling psychrometer consists of two thermometers connected to a handle by a swivel, (1), figure 1-1, so that they may be whirled in the air as shown in (3), figure 1-1. The bulb of one of these thermometers is covered by a cloth wick that is moistened with water at the same temperature as the surrounding air, (2), figure 1-1. This must be done before taking a reading. The wick and water must be clean and free of soap. Now whirl the thermometers rapidly to evaporate moisture from the wick (3), fig. 1-1). Read both thermometers and whirl the instrument again. Repeat this process until

the wet bulb settles at the lowest point it will reach. This is the wet-bulb reading. Note the dry-bulb reading also. By plotting the intersection of the wet- and dry-bulb temperatures on the psychrometric chart, the humidity can be determined. As an example, for measured air temperatures of 80°F. dry bulb and 60°F. wet bulb, the intersection of the vertical 80°F. dry-bulb line and the diagonal 60°F. wet-bulb line on the psychrometric chart, appendix C, coincides with a relative humidity of 30 percent (curved line) and a specific humidity of 46 grains per pound of dry air (horizontal line).

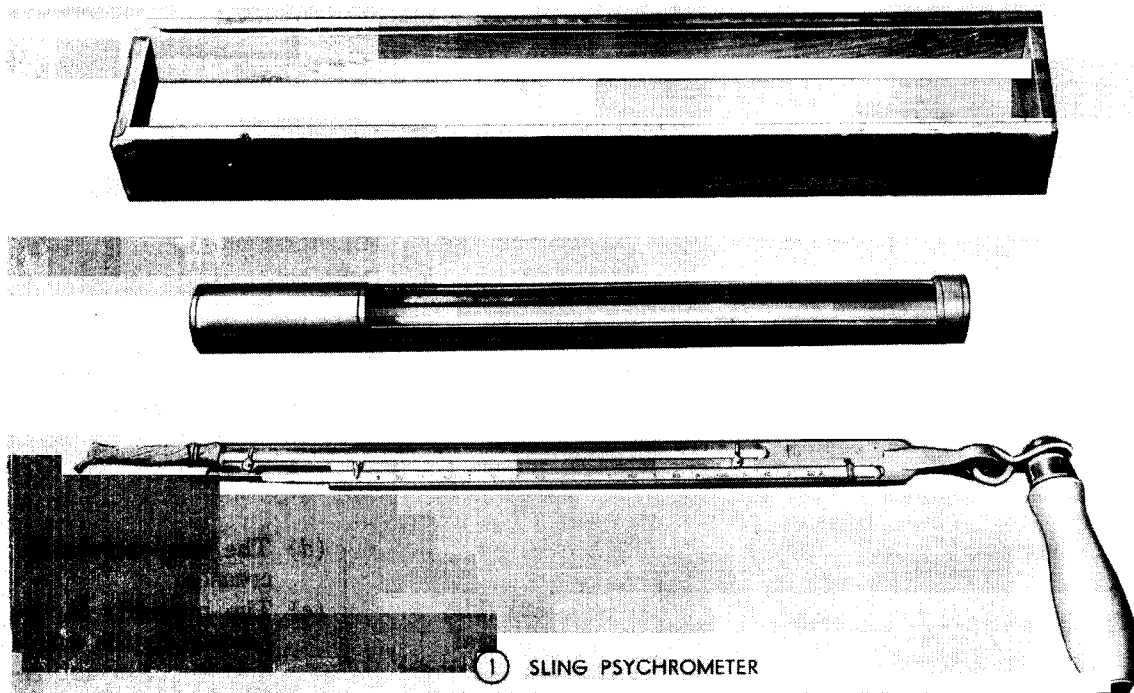
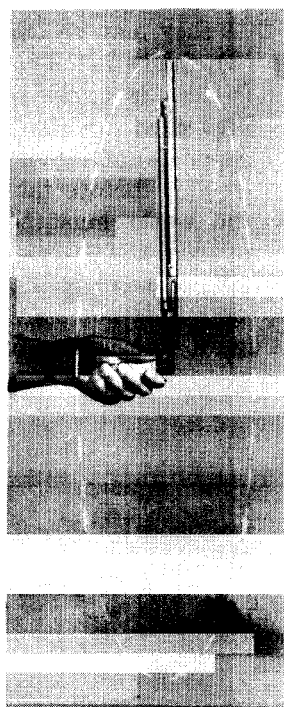


Figure 1-1. Measuring humidity with a sling psychrometer.



② MOISTENING PSYCHROMETER WICK

Figure 1-1—Continued.



③ METHOD OF OBTAINING READING

Figure 1-1—Continued.

Section III. HUMAN COMFORT

1-7. Environmental Factors

a. The comfort of human beings is affected by several qualities of the air that surrounds them, including dry-bulb temperature, humidity, air motion, and presence of airborne solids or odors. Human occupancy of confined space produces at least five changes in the conditions of the air that can affect comfort:

(1) The chemical environment

- (a) The carbon dioxide content is increased.
- (b) The oxygen content is decreased.
- (c) Products of decomposition, accompanied by odors, are given off.

(2) The thermal environment

- (d) The temperature increases.
- (e) The humidity is increased by the evaporation of moisture from the skin and lungs.

b. Control over the chemical environment is not normally a concern, because ventilation, either natural or forced, with pure outside air can usually maintain a conservatively low concentration of carbon dioxide and a safe concentration of oxygen. There are, however, some spaces designed for human habitation such as deep mines, submarines, and shelters where air ventilation is not feasible. In these spaces, con-

trol over the chemical environment can provide several advantages, including:

(1) The shelter may be able to be occupied longer after shutdown of the ventilating system.

(2) Only intermittent operation of a manual blower may become practicable to maintain an acceptable quality of air in the space.

(3) It may be possible also to control the thermal environment (temperature, humidity, etc.) and the air distribution, without supplementary apparatus.

c. Three procedures may be used to control the thermal environment in a shelter where excess heat may become a problem.

(1) Cooling by forced or natural ventilation with outside air.

(2) Cooling by the effects of heat conduction into the surrounding earth.

(3) Mechanical cooling and dehumidifying with refrigeration or well water.

Various combinations may be used. In general, only method (3) provides positive and *reliable* control of temperature, humidity, and moisture condensation for improved human comfort.

1-8. Effective Temperature

Temperature, humidity, and air motion combine to produce a feeling of relative comfort or discomfort, in a given space. This relationship is not mathematical but has been determined by tests on groups of individuals who reported their reaction to various air conditions. Based on this work, the scale of "Effective Temperature" (or "Comfort Index") was developed to represent the combined effect of these three qualities. Other work of this nature has been done to determine the conditions under which a maximum number of people will feel comfortable. The results of these tests are shown, along with the effective temperature index for still air conditions, in the "comfort chart" presented in appendix D. Here is an example of how the comfort chart works. Assume that the outside temperature is 70° and the relative humidity is 50 percent. Locate the 70° line at the

bottom of the page. Locate the 50 percent humidity line on the right side of the page. Follow these two lines until they intersect. A third line will cross through the point of intersection. Follow this line up the page to the chart entitled "percent of subjects feeling comfortable." At the bottom of this chart read the effective temperature. In this example the effective temperature is 66°. Follow this line up the chart until it intersects the bell curve. Reading on the left side of the chart, the percent of subjects that feel comfortable is 30 percent. There is a difference between the temperature most desired in the winter and that most desired in the summer, the most desired temperature being about 2 degrees warmer than the most desired winter temperature. There is an appreciable zone of comfort in both summer and winter, the majority of people being comfortable over a range of several degrees.

1-9. Odor Control

a. *Purpose.* People indoors bring about changes in the composition of the air around them, consuming small quantities of oxygen and giving off carbon dioxide. The quantities changed are extremely small and unless people are in an airtight space, such as a submarine, the amount of air required to supply sufficient oxygen is of no practical importance. Nevertheless, air can become stale and unpleasant in crowded places because of the presence of objectionable odors.

b. *Sources of Odor.* The chief sources of objectionable odors include human or animal bodies, tobacco smoke, cooking, and manufacturing or combustion processes. Problems of odor control are particularly severe in confined spaces. Odors from people or from other sources which would be diluted to an unnoticeable level in a large room might become objectionable in a small one.

c. *Methods of Odor Removal.* Wherever odors are created at a localized source, such as in cooking, manufacturing, and combustion processes, they can be most effectively removed by the use of a hood and exhaust duct arranged to trap them at the source and remove them before they spread. Body odors, tobacco smoke,

and other odors which are released within living spaces usually are removed or diluted to an unobjectionable level by ventilating with quantities of odor-free air. This usually means outside air but may be air made up entirely or in part of air which has been cleared of odors by washing or passing over odor-absorbing material. The quantity of fresh air required to remove odors varies from 5 cubic feet per minute per person, where the concentration of people is not great and there is no smoking done, to 50 cubic feet per minute per person where the space is confined, smoking extreme, and a need for low odor concentration exists. Under average conditions, required outside air quantities range from 10 to 30 cubic feet per minute per person with a higher figure being used when there is much smoking done.

1-10. Air Cleanliness

Of the atmospheric contaminants discussed in paragraph 1-3c, solid dust particles and plant pollen may be particularly undesirable from the standpoint of human health and comfort. In addition to being unsightly, dust particles

can serve as carriers of harmful bacteria. Large concentrations of ragweed and other objectionable plant pollens also cause extreme discomfort to persons allergic to them. Fortunately both of these solid contaminants, dust and pollen, as shown in appendix B, are of sufficient size to be effectively caught on simple air filters. Tobacco and other smokes can only be removed by passage through an electrostatic cleaner or over an absorbing medium such as activated carbon.

1-11. Hospital Air Conditioning

The proper conditioning of air in hospital operating rooms and recovery wards has proven to be particularly valuable for several reasons: ventilation, by reducing the concentration of anesthetic gases, reduces the explosion hazard; comfortable air conditions increase both the patients' recuperative powers and the efficiency of operating personnel; and filtration of circulated air reduces the possibility of airborne infection and removes pollen and other allergens detrimental to some patients.